Atmospheric Dispersion Simulation of Fukushima Daiichi(1F) Accident

Hiroko Kido, Ph.D.

Visible Information Center, Inc.

September 10 – 11, 2014

International MACCS Users Group Meeting

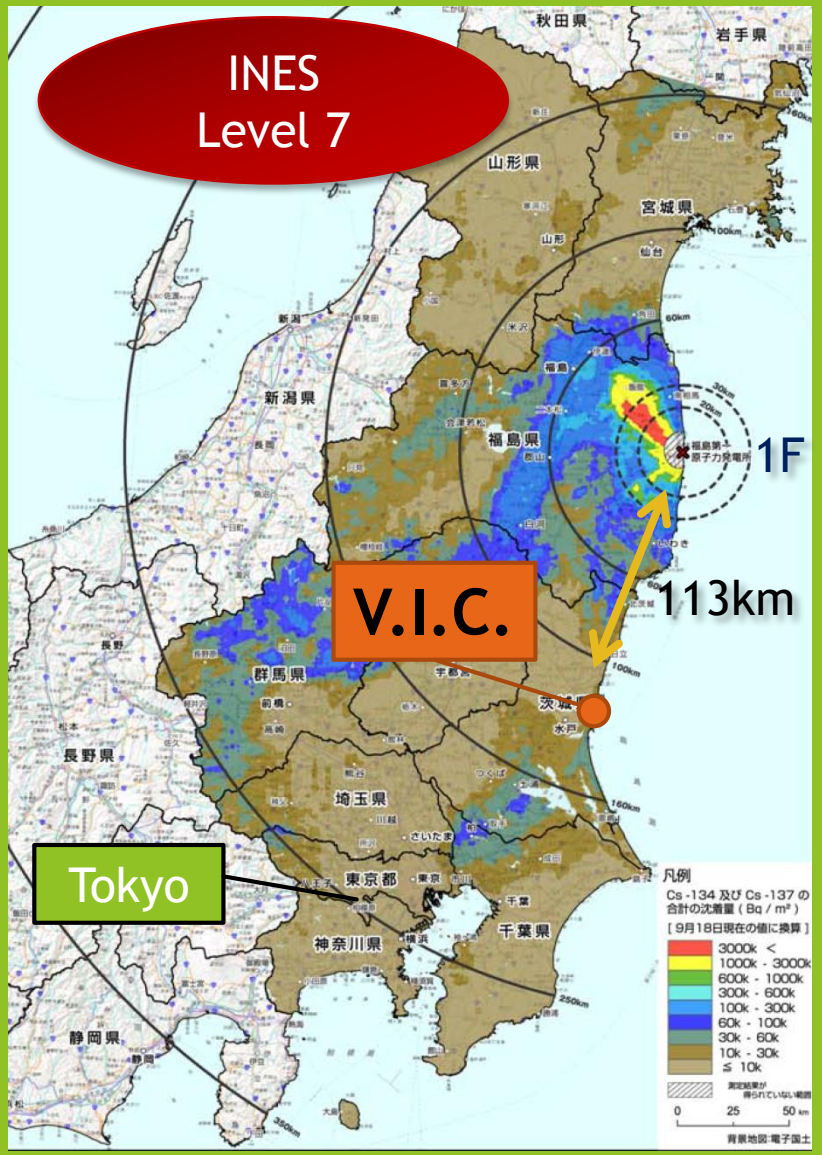
Bethesda MD USA

Overview of the Incident

- All power sources of 1F were lost due to the Tohoku-Pacific Ocean Earthquake on March 11, 2011.
- Nuclear reactors 1, 2, and 3 were out of control and in meltdown.

  Hydrogen was generated by chemical reactions between Zr and water.

- Hydrogen explosions occurred in reactor housing 1, 3, and 4.
- A large amount of radioactive substances was released into the environment.



Deposition of ^{137}Cs, ^{134}Cs by the third airborne monitoring (MEXT)

Contents

Introduction

In this study, we conducted two types of assessments. First a Rapid Assessment and then a Detailed Assessment.

We started Rapid Assessment on March 15, 2011 using GPV* meteorological data and estimated the source term available in that period. Consistency between the resulting plume movement and the measured increase of dose rates suggests that the radioactive plume originated from 1F.

Detailed Assessment allows detail calculation of a targeted area. Iitate village located 30 to 45 km north west from 1F was designated as a deliberate evacuation area but measured dose data were scarce in the first month after the accident.
Early doses of Iitate people were evaluated in this study.

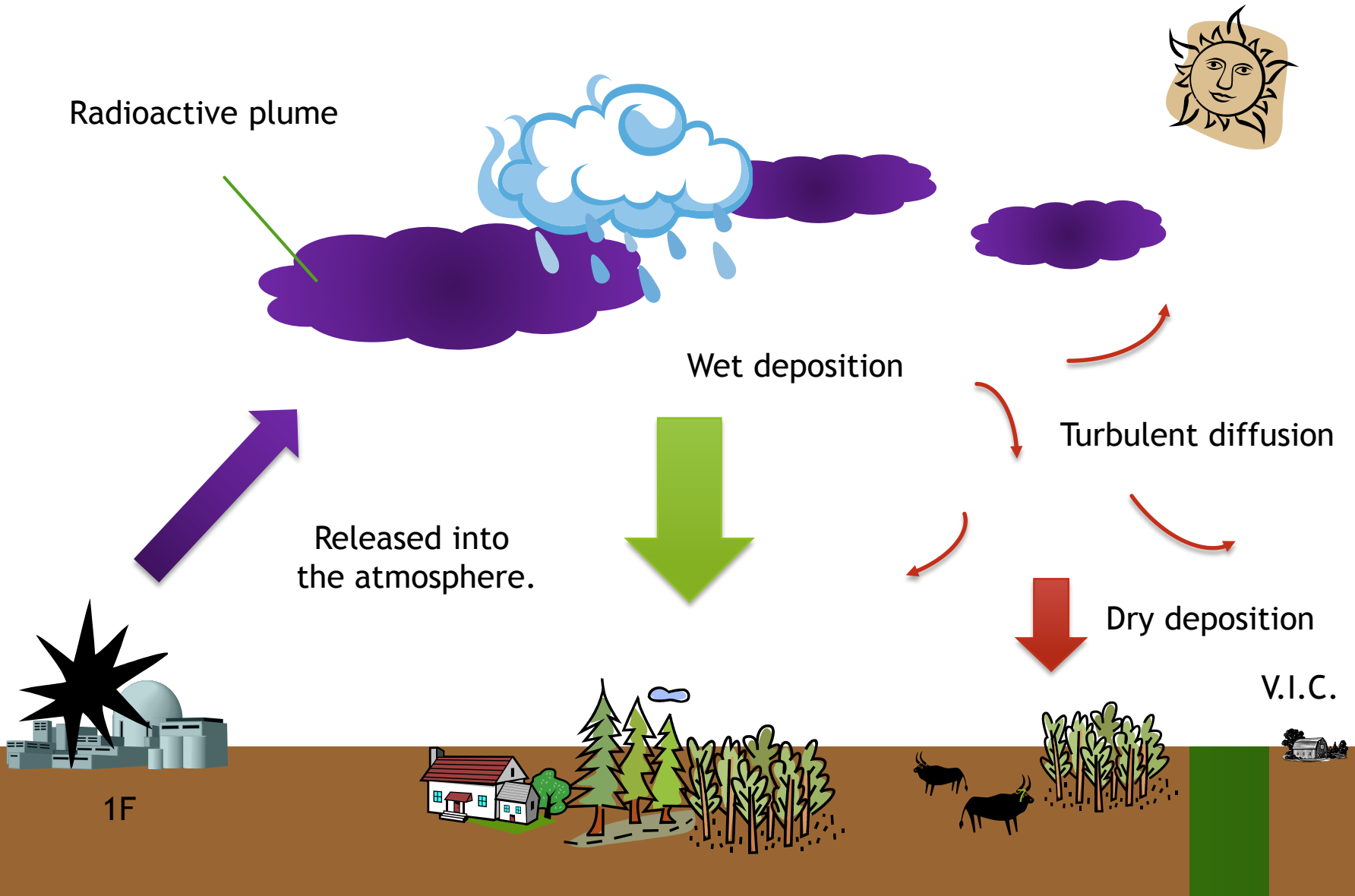
*GPV: Grid Point Value

Part 1.
Rapid Assessment

Rapid Assessment Purpose

- Find plume's point of origin
  - (1F? Or other nuclear facilities?)
- Find current distribution of radioactive plume.
- Which area is contaminated?

The behavior of the released radioactivity



Atmospheric Dispersion Models Which should I use ?

Plume model

- Can make quick assessment
- Requires site meteorological data

Unsuitable for large area with complex topography

Puff model

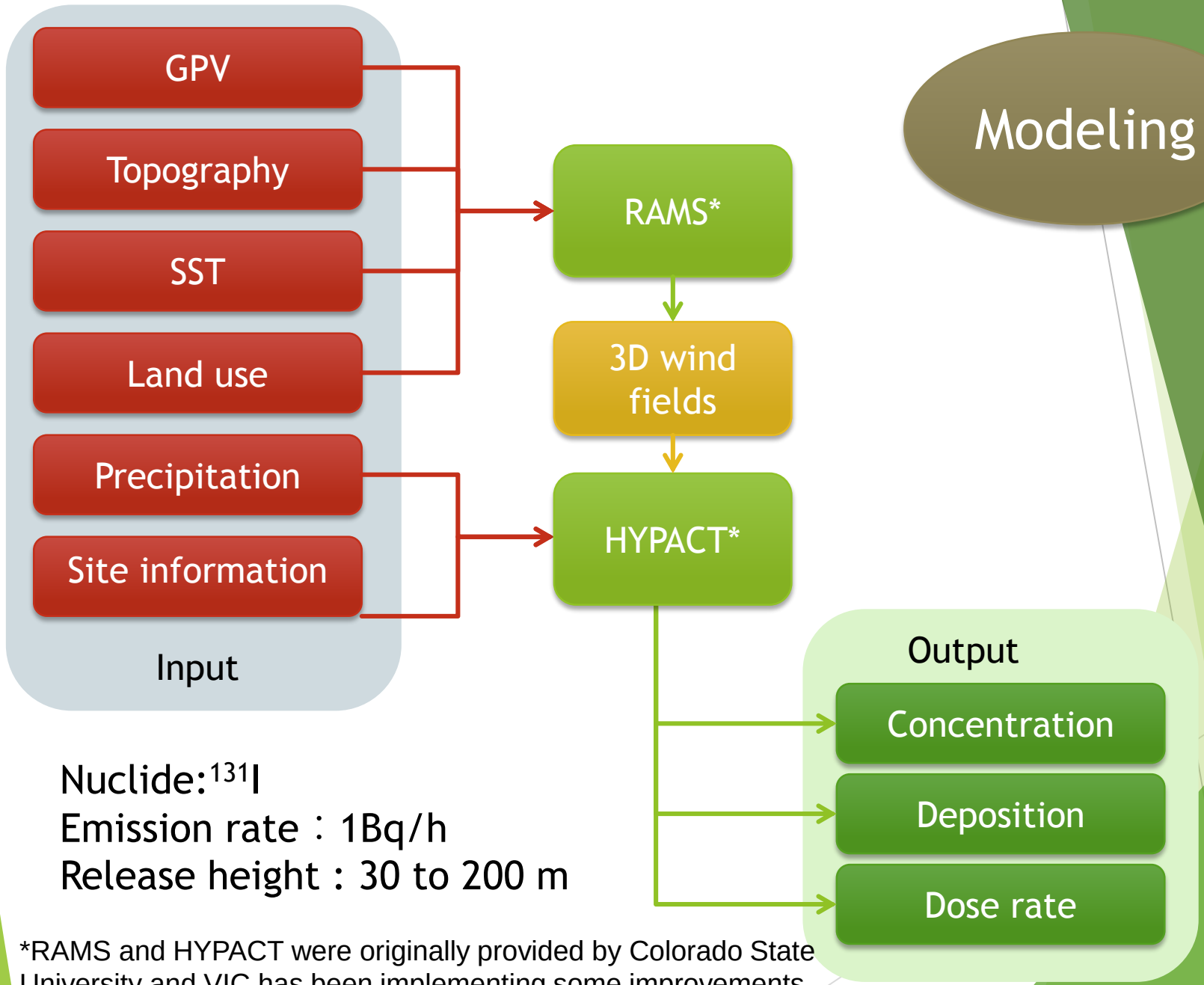
- Can make fast assessment
- Requires meteorological data (surrounding area)

Met. observation stations around 1F were destroyed therefore data could not be obtained

Meteorological model + transport model

- Can reproduce meteorological field from GPV*
- Is suitable for complex topography and large areas.
- Can predict the movement of radiation plumes

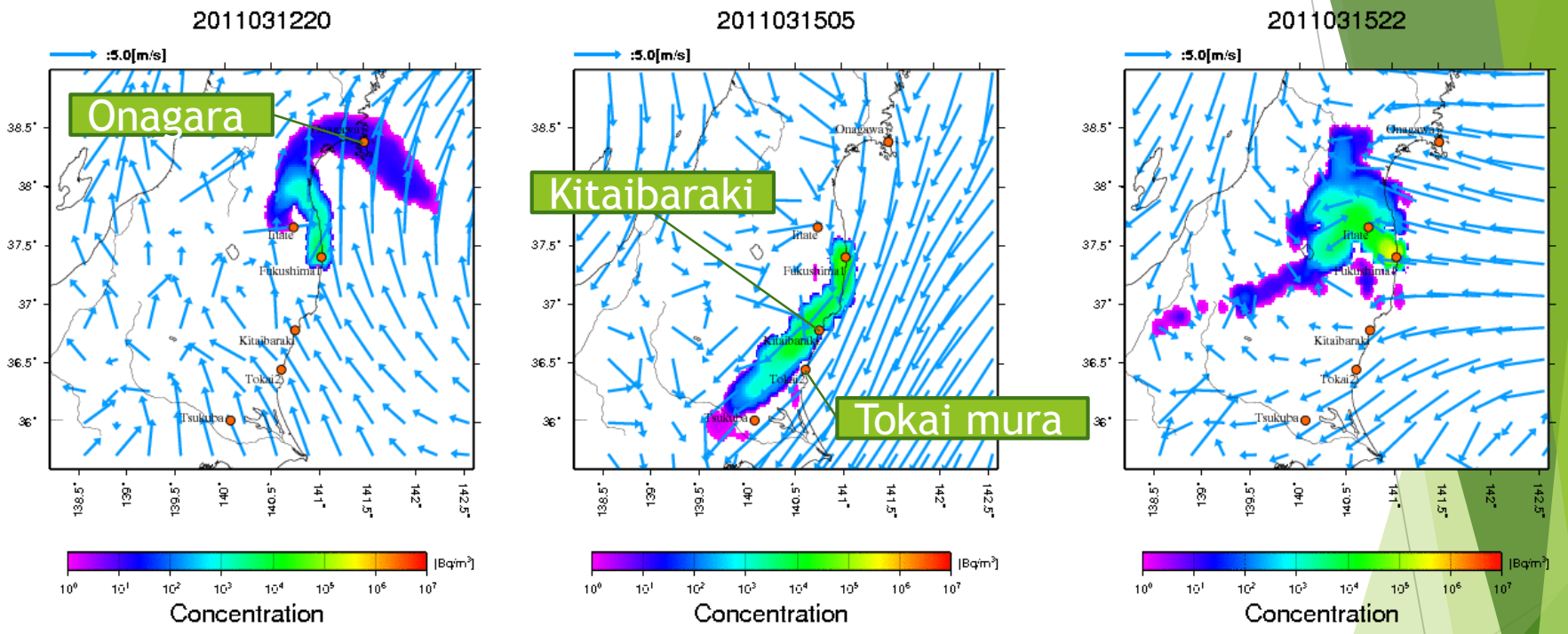
Modeling



Nuclide: ^{131}I
Emission rate : 1Bq/h
Release height : 30 to 200 m

*RAMS and HYPACT were originally provided by Colorado State University and VIC has been implementing some improvements.

Comparison Between Reality and Simulation

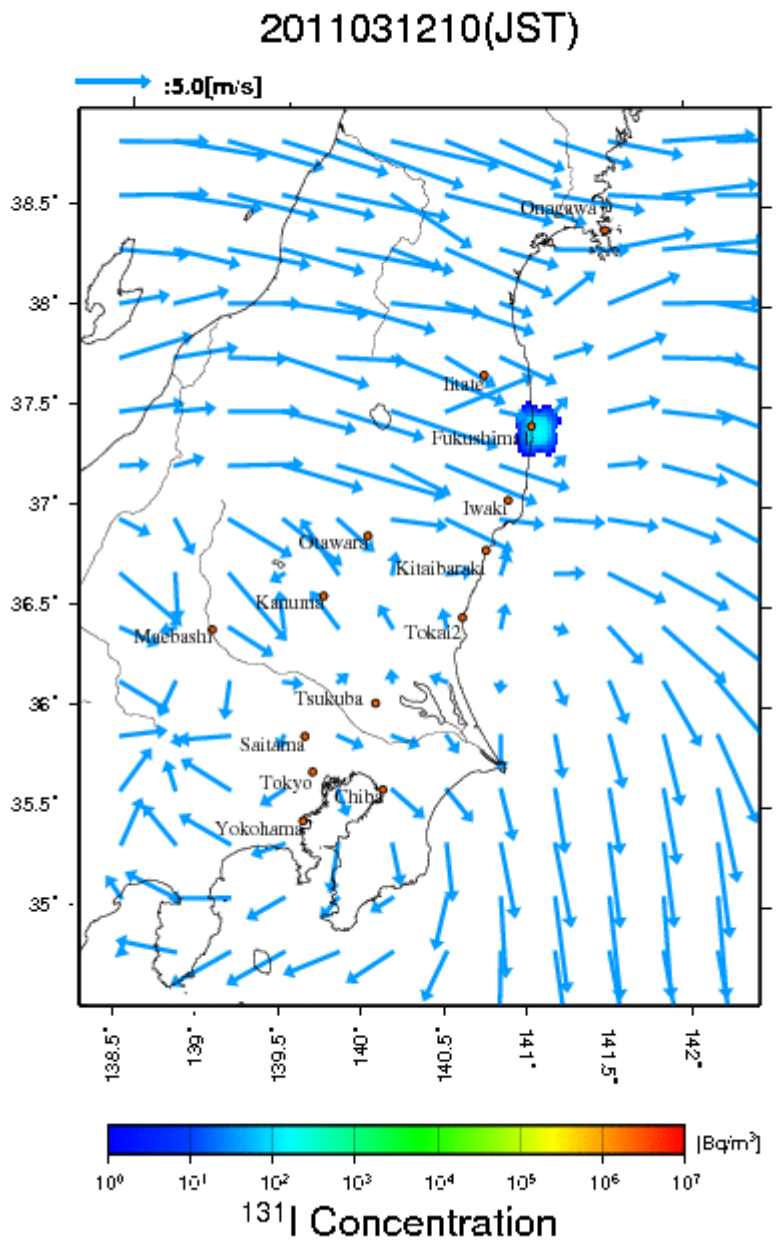


21:00 March 12
21μSv/h measured at Onagawa

4:00 to 7:00 March 15
5μSv/h measured at Kitaibaraki city, and Tokai-mura

19:00 March 15 to 3:00 March 16 plume was stagnant at north west (Iitate Village) of 1F

Resulting plume movement and measured increase of dose rates are consistent.



Plume Movement

- March 12 21:00 Onagawa
- March 15 early morning
  Kitaibaraki, and Tokai
- March 15 10:37 Wako(Riken)
- March 15-16 Iitate village
- March 21 Kanto area

See more
http://www.vic.jp

Results

- **Resulting plume movement and measured increase of dose rates in the Kanto area are consistent. It suggests that the radioactive plume originated from 1F.**
- **The plume swept over the Kanto area on the15 and again on March 20 to 21, 2011.**
- **19:00 March 15 to 3:00 March 16, the radioactive plume was stagnant at north west of 1F.**

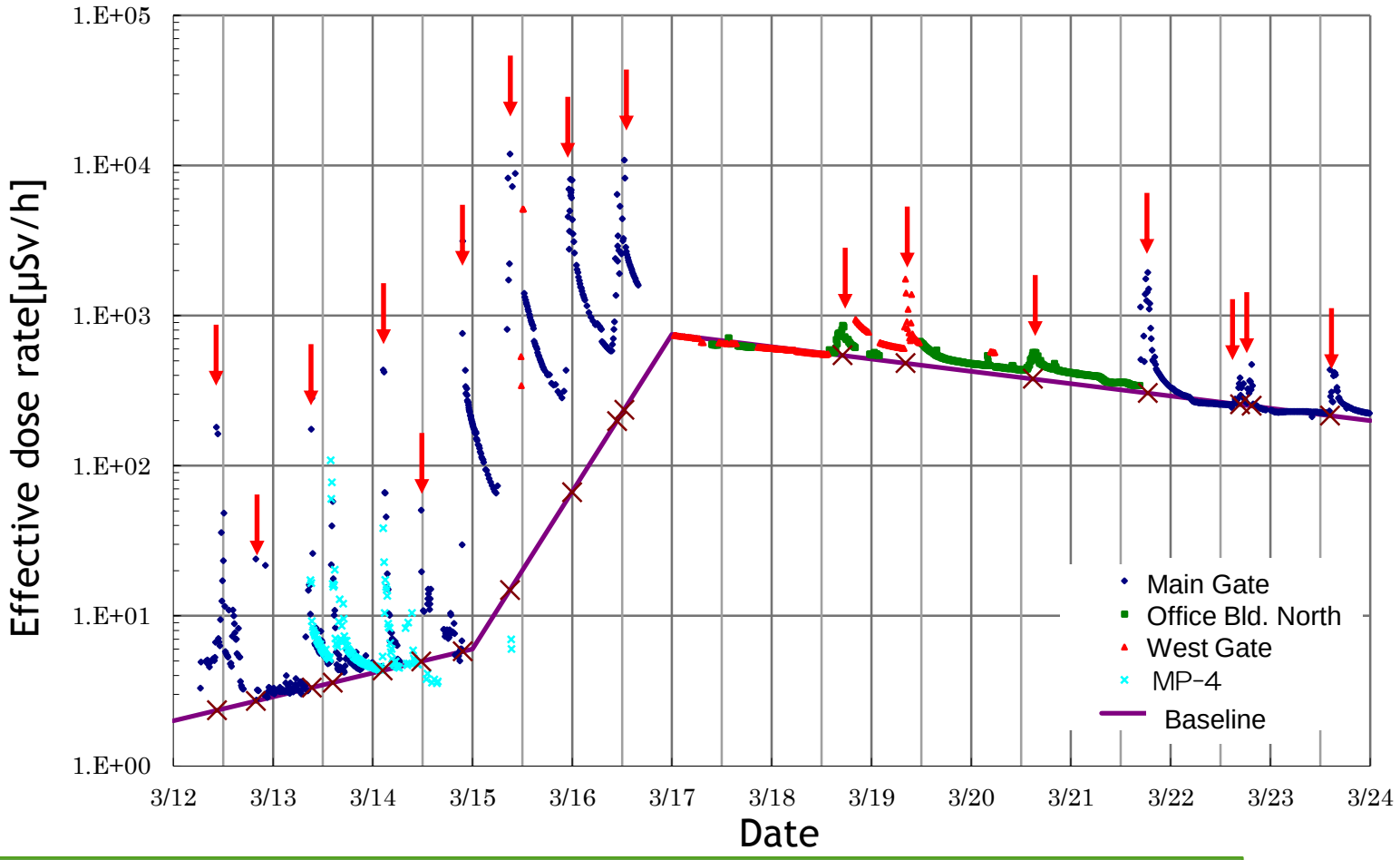
Next

- **Which areas receive a high level of radioactive contamination?**

  Evaluation needs source term. However, at that time, only measured dose rate and estimated total amount of ^{131}I (=1.1×10^{17}(Bq)) announced by JAEA were available.

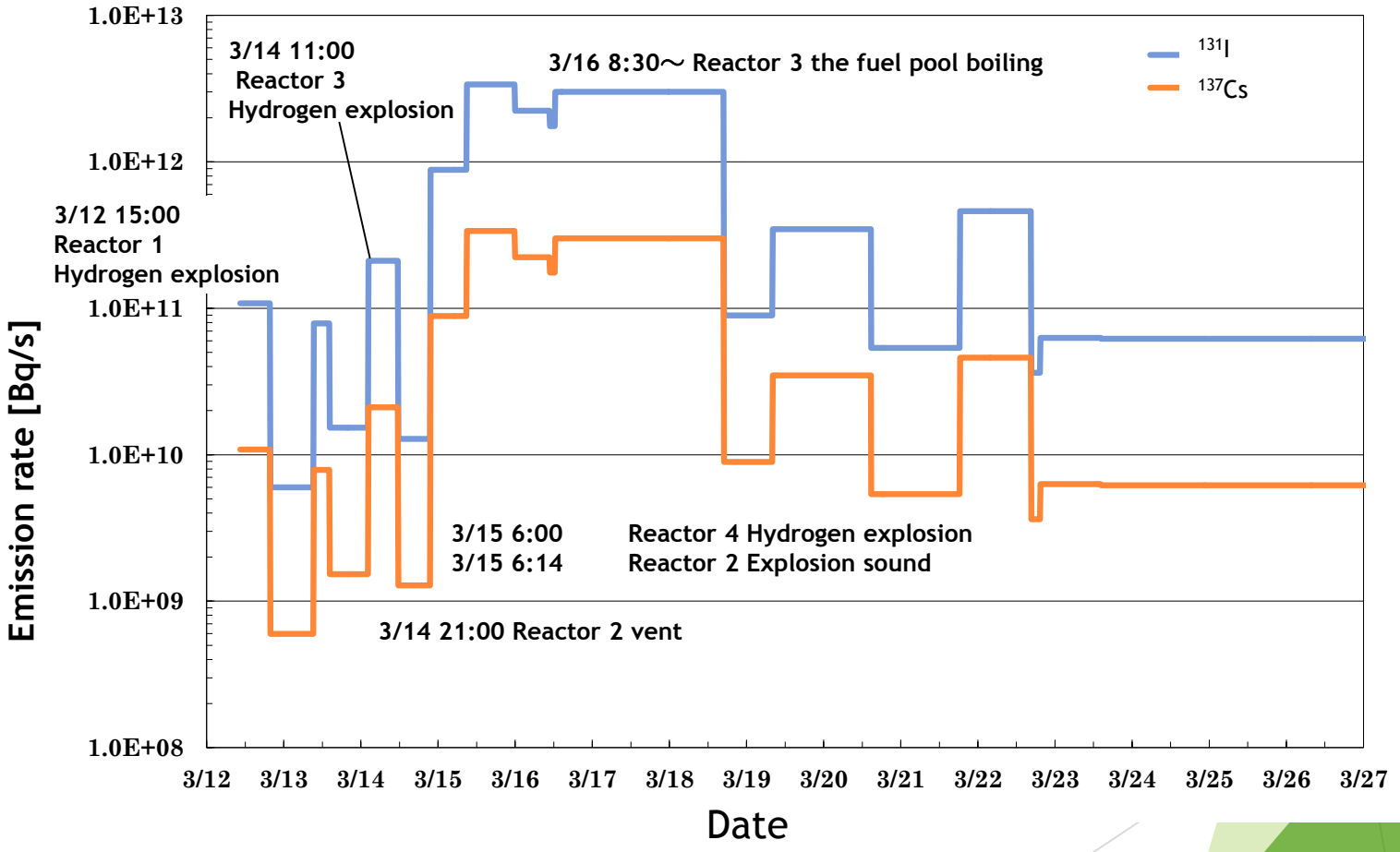
We estimate source term of ^{137}Cs based on these data.

Effective Dose Rate around 1F



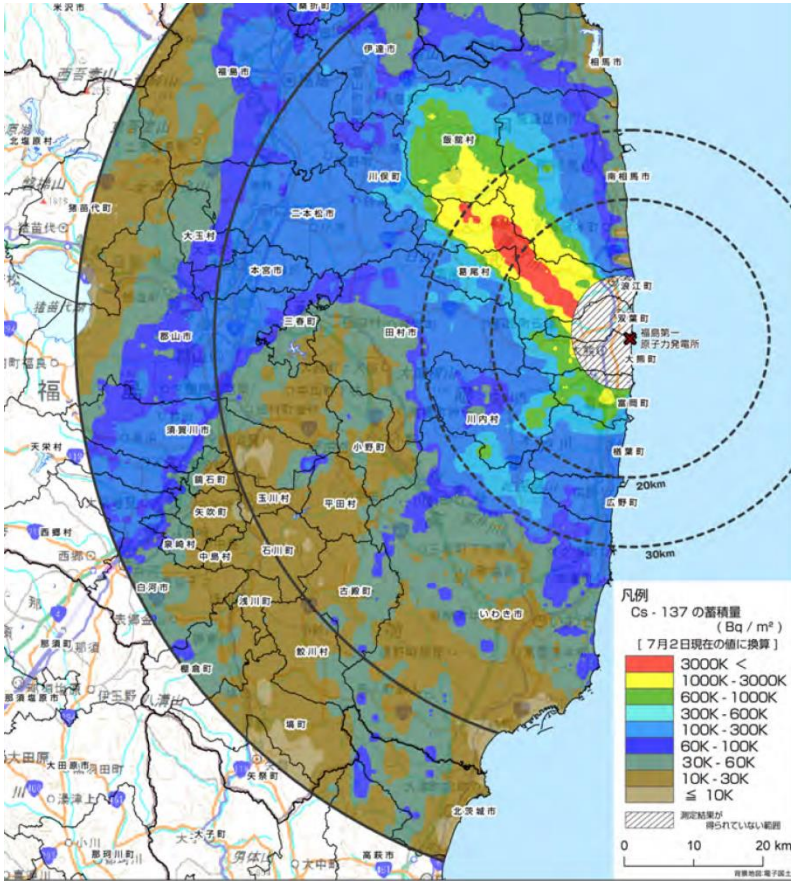
Increase of dose rate suggests emission occurrences of radioactive substances (arrows).

Estimation of Source Term

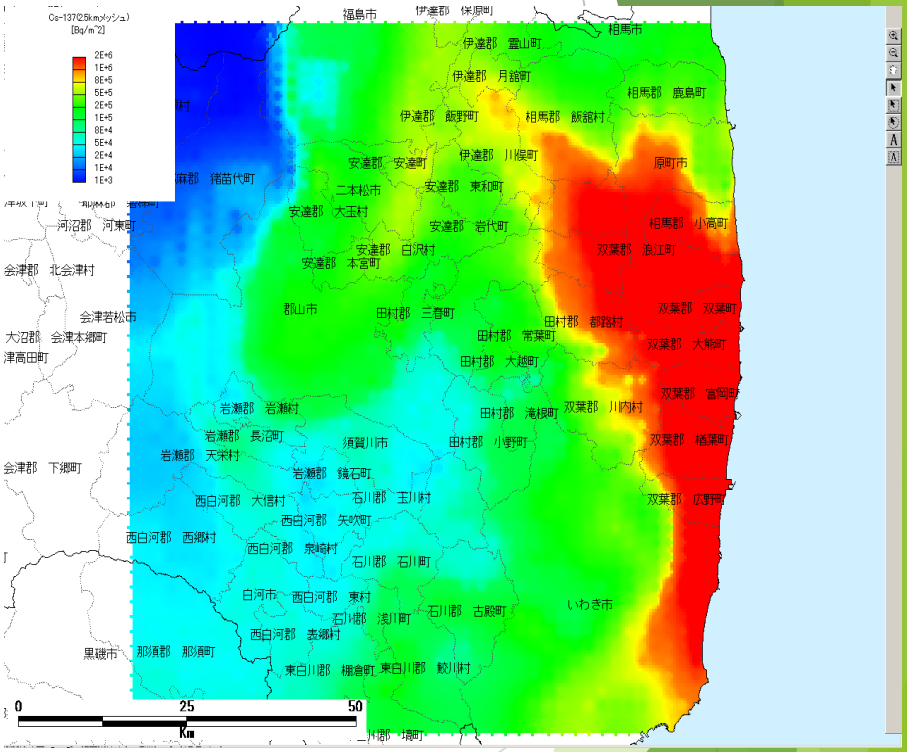


Time of change for ^{131}I emission rates was estimated based on total amount of 1.1×10^{17}[Bq] announced by JAEA with measured dose rate time change. ^{137}Cs was assumed to be one-tenth of ^{131}I.

Comparison of ^{137}Cs Deposition between Simulation and Measurement in Fukushima

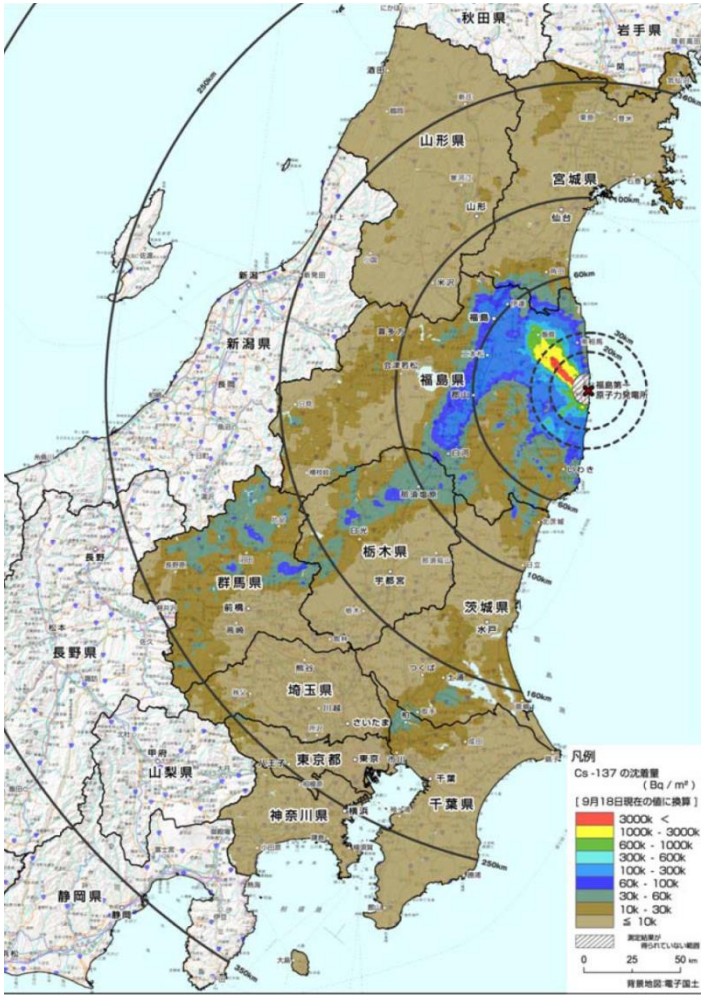


Deposition of ^{137}Cs by the third airborne monitoring (MEXT) on July 8, 2011

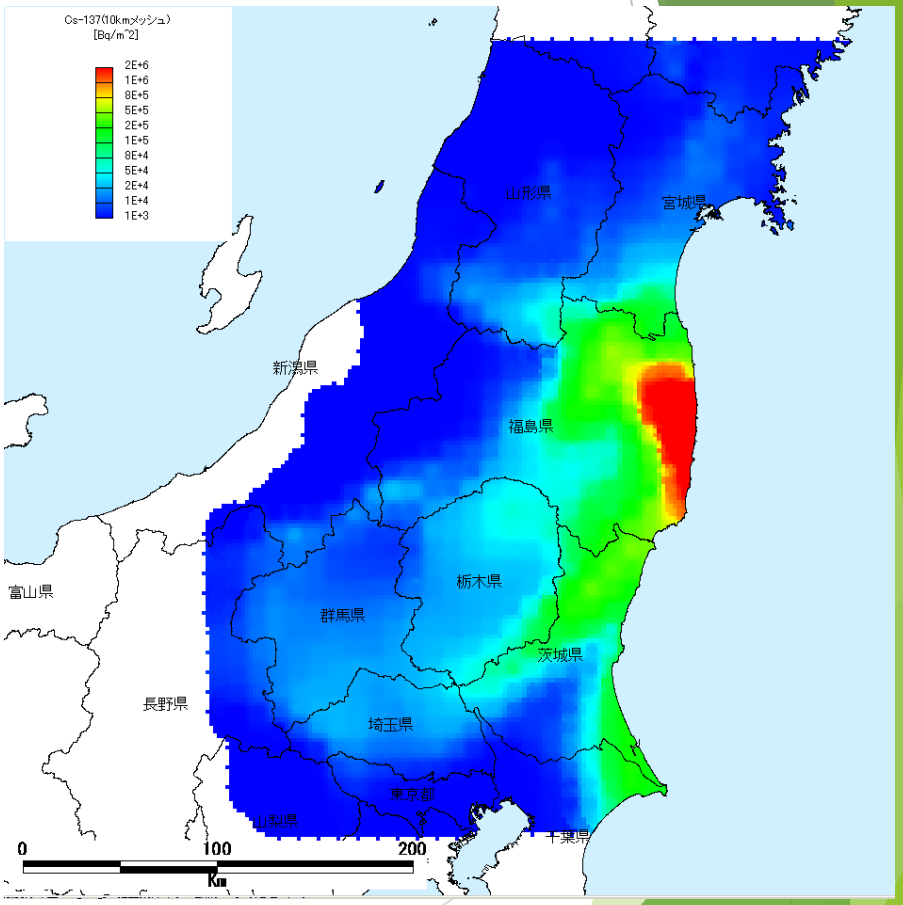


Simulation (April 4, 2011)

Comparison of ^{137}Cs Deposition between Simulation and Measurement in Kanto Area



Deposition of ^{137}Cs by the third airborne monitoring (MEXT) on July 8, 2011



Simulation(April 4, 2011)

Summary

The possible outcomes by different available input data in the rapid assessment.

If only meteorological data is available

- Prediction of distribution of radioactive plume.
- Prediction of high dose area after the accident.

The fragmentary measured data(dose rate , dust sampling)

- Rough estimation of amount of source term.
- Rough estimation of amount of deposition, exposure dose.

Time dependent dust sampling data

- The inverse estimation of the detailed source term.
- Prediction of detailed deposition, and exposure dose.

Part 2.
Detailed Assessment

After the accident

Problem

- The source term and early dose of the Fukushima Accident is not clear because in March 2011 measured data from around 1F was scarce.

Researchers try to estimate the source term and early dose more accurately.

In this study

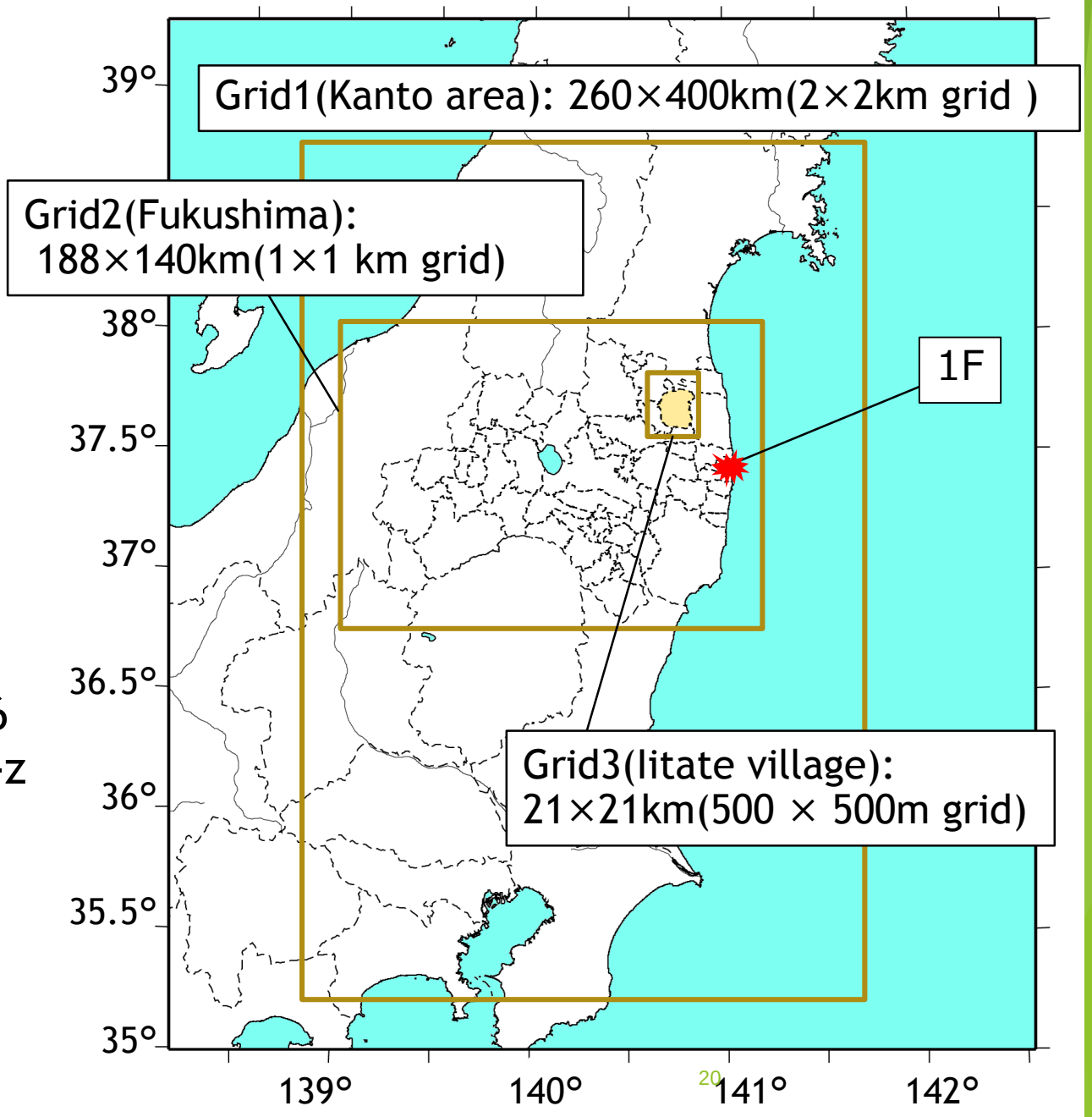
- The early dose due to ^{131}I uptake in Iitate village located 30 to 45 km from 1F was estimated.

Iitate village was included neither in evacuation nor in a sheltering area. On April 22, 2011, Japanese government designated Iitate village as a deliberate evacuation area which would be subjected to higher than 20mSv/year. However, dose of Iitate village people at first month had not yet been evaluated because of shortage of measured data.

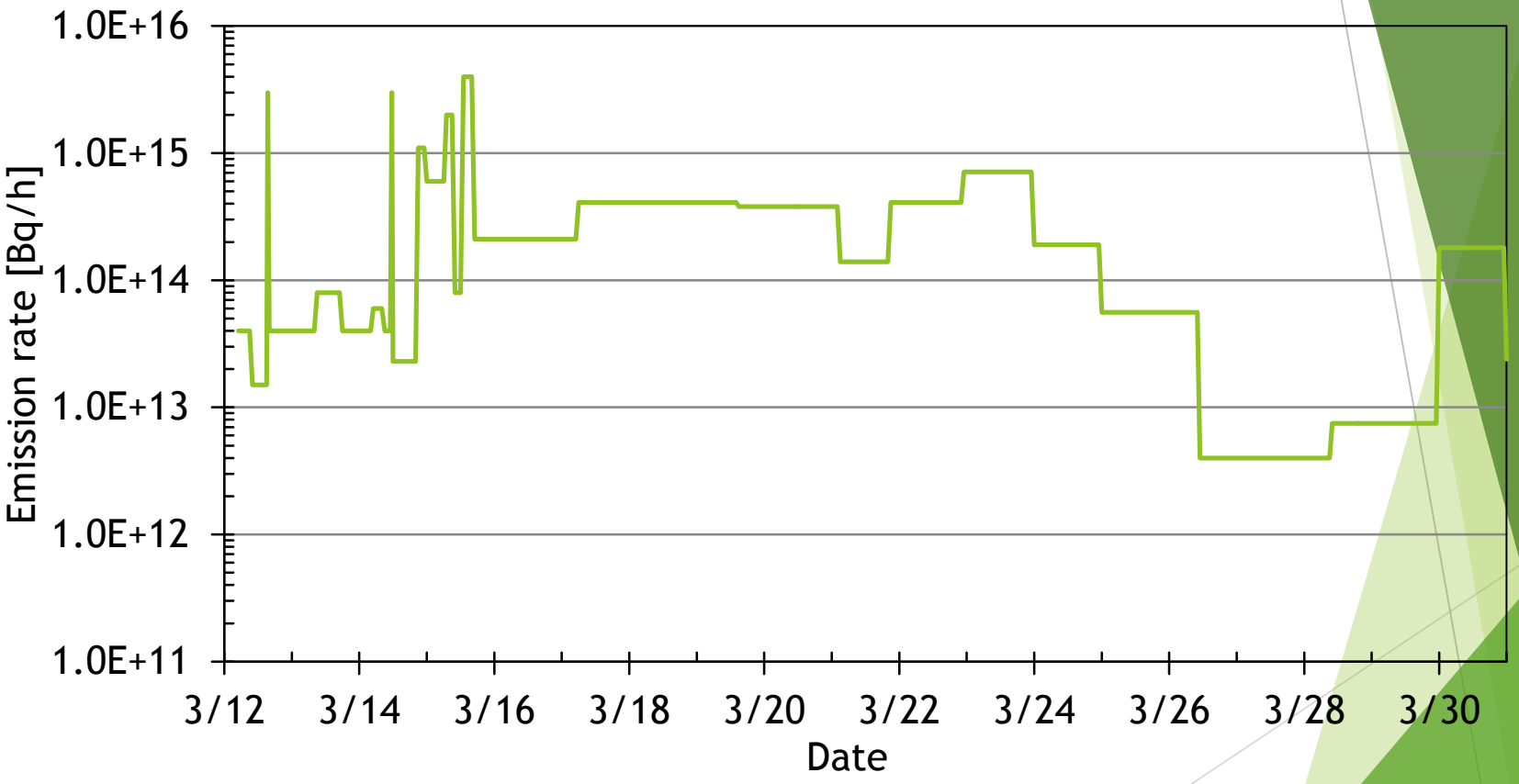
Grid Structure

Vertical grid

The vertical calculation space extended to an altitude of 20km divided into the 36 levels using sigma-z coordinate.

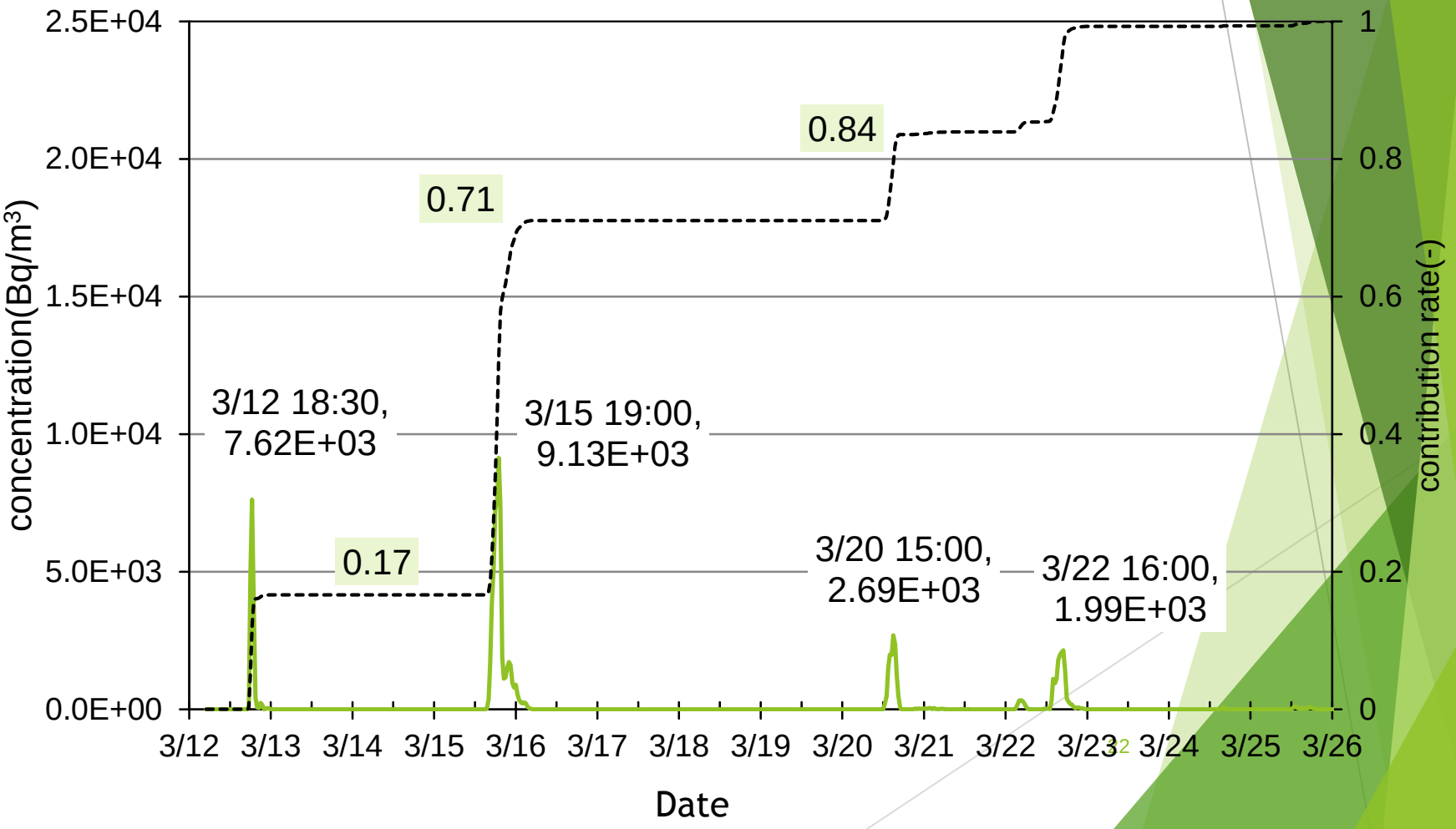


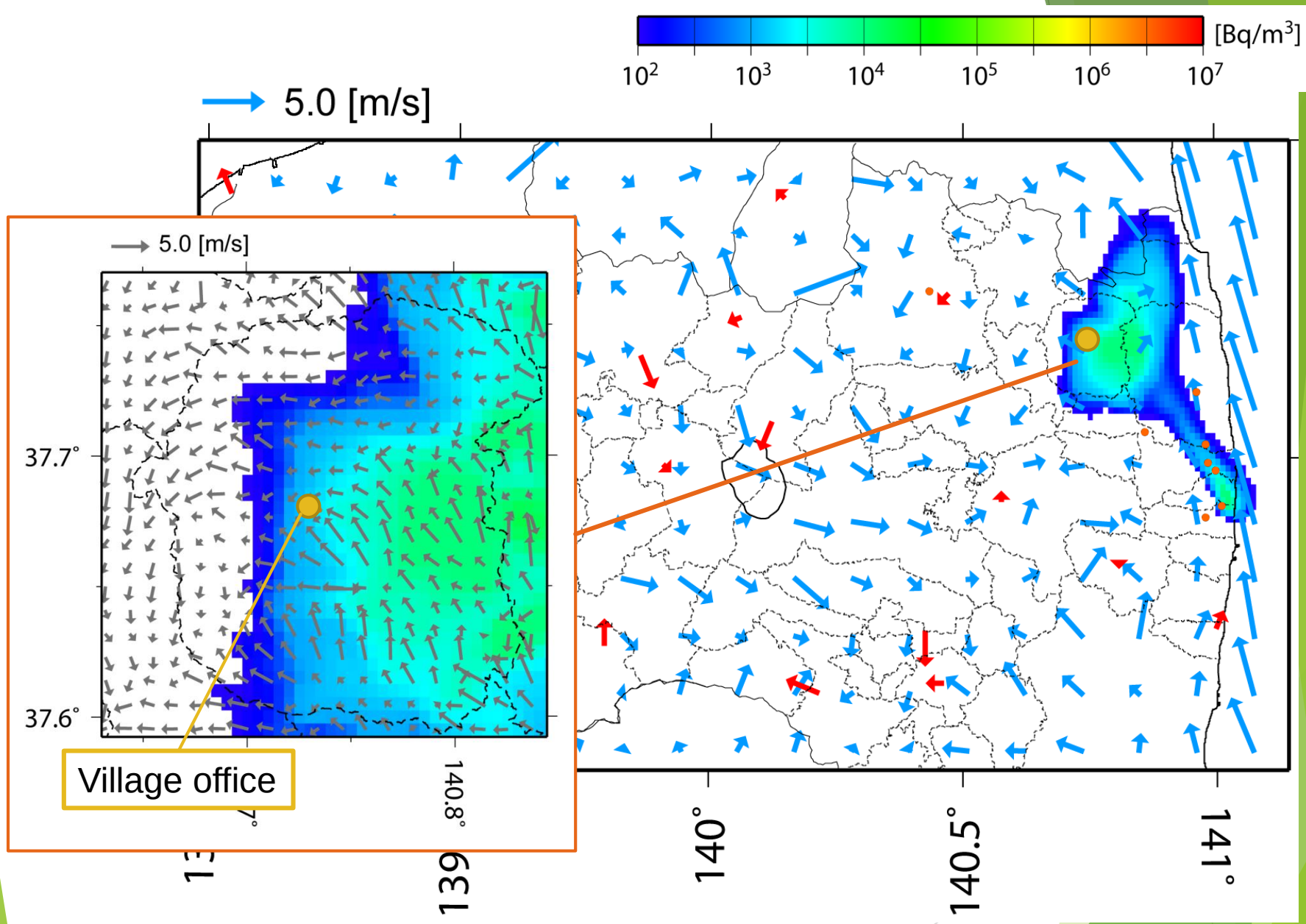
^{131}I Source Term



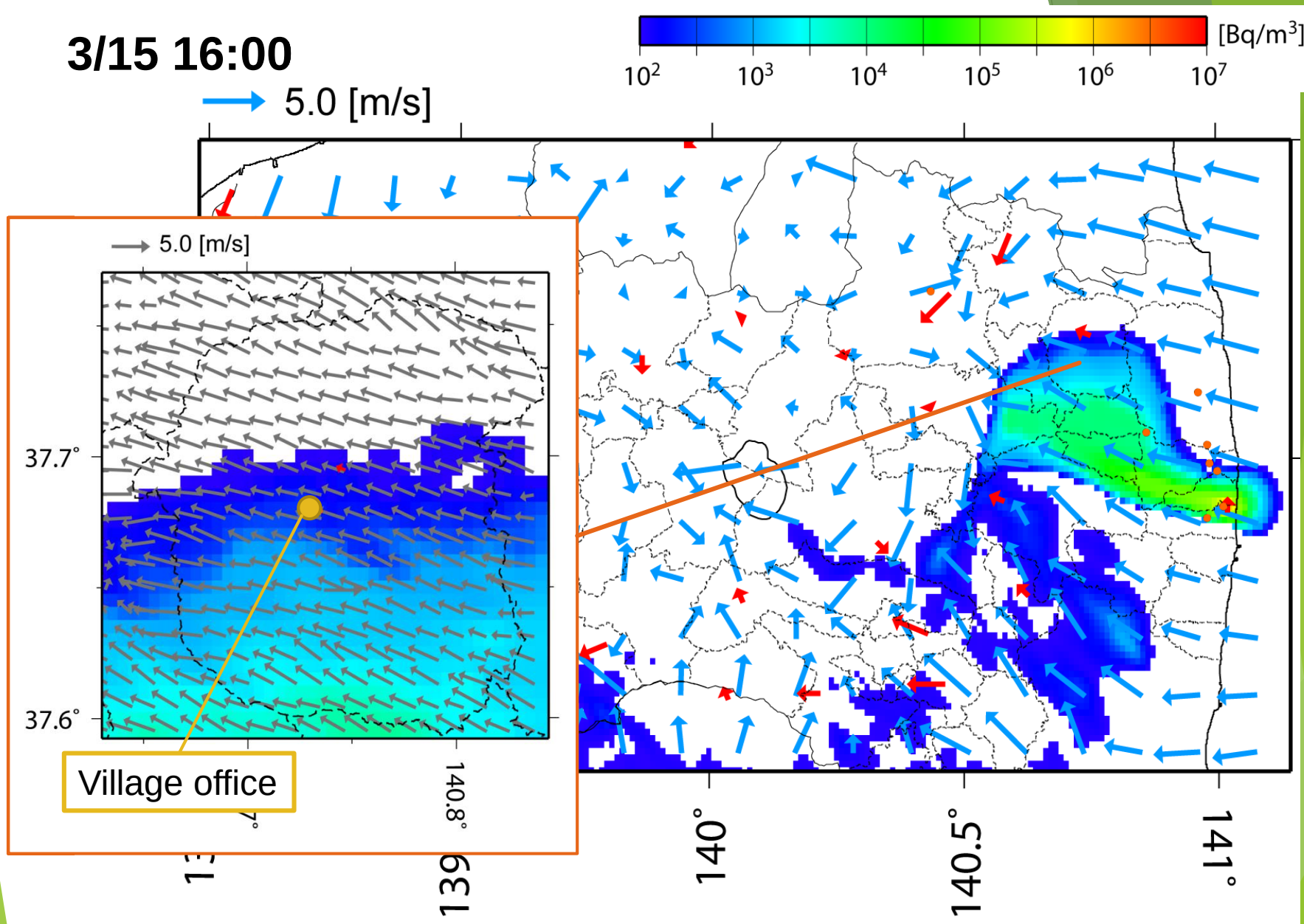
Reference: Nuclear Regulation Authority

Calculated ^{131}I Atmospheric Concentration in Iitate Village

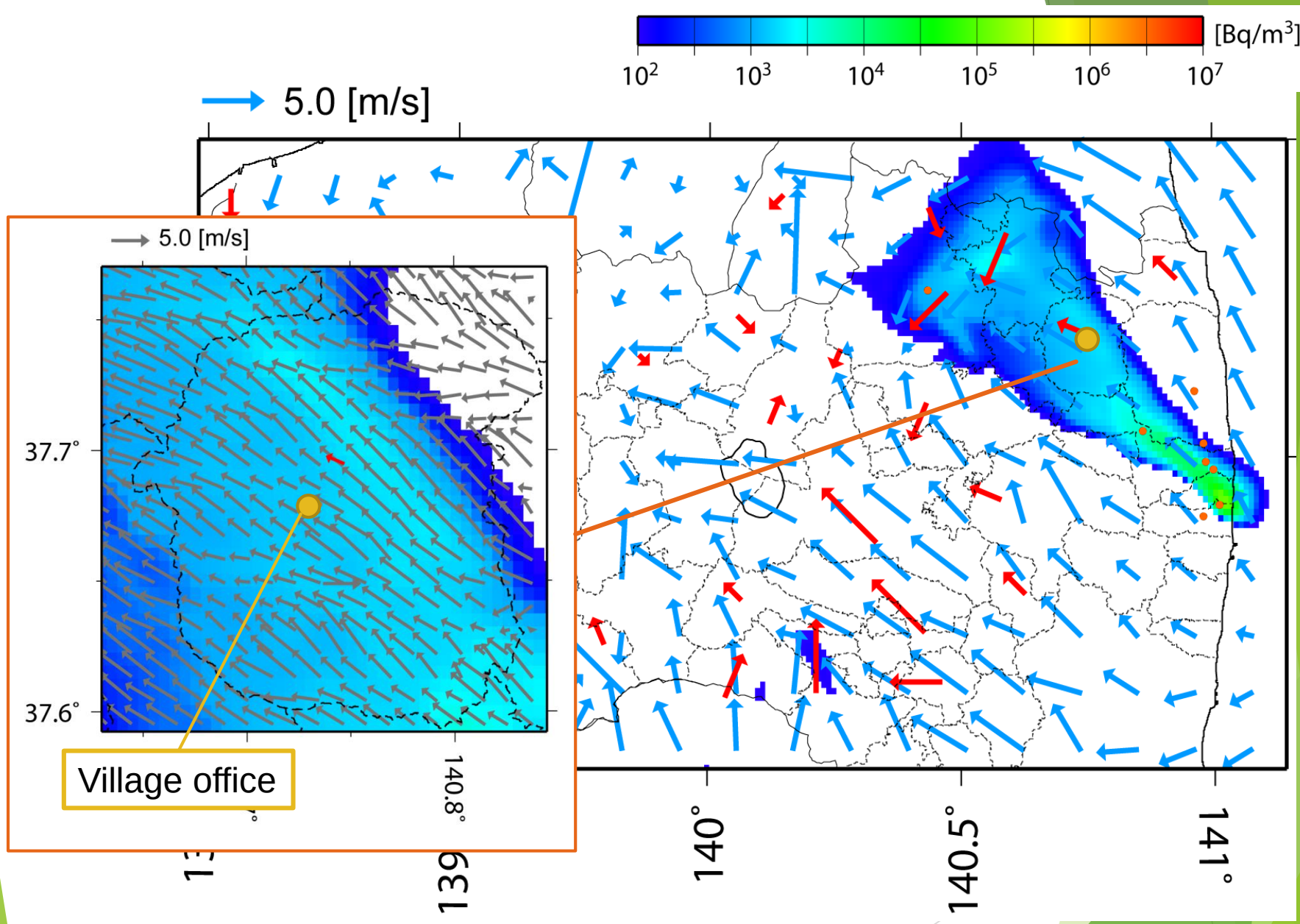




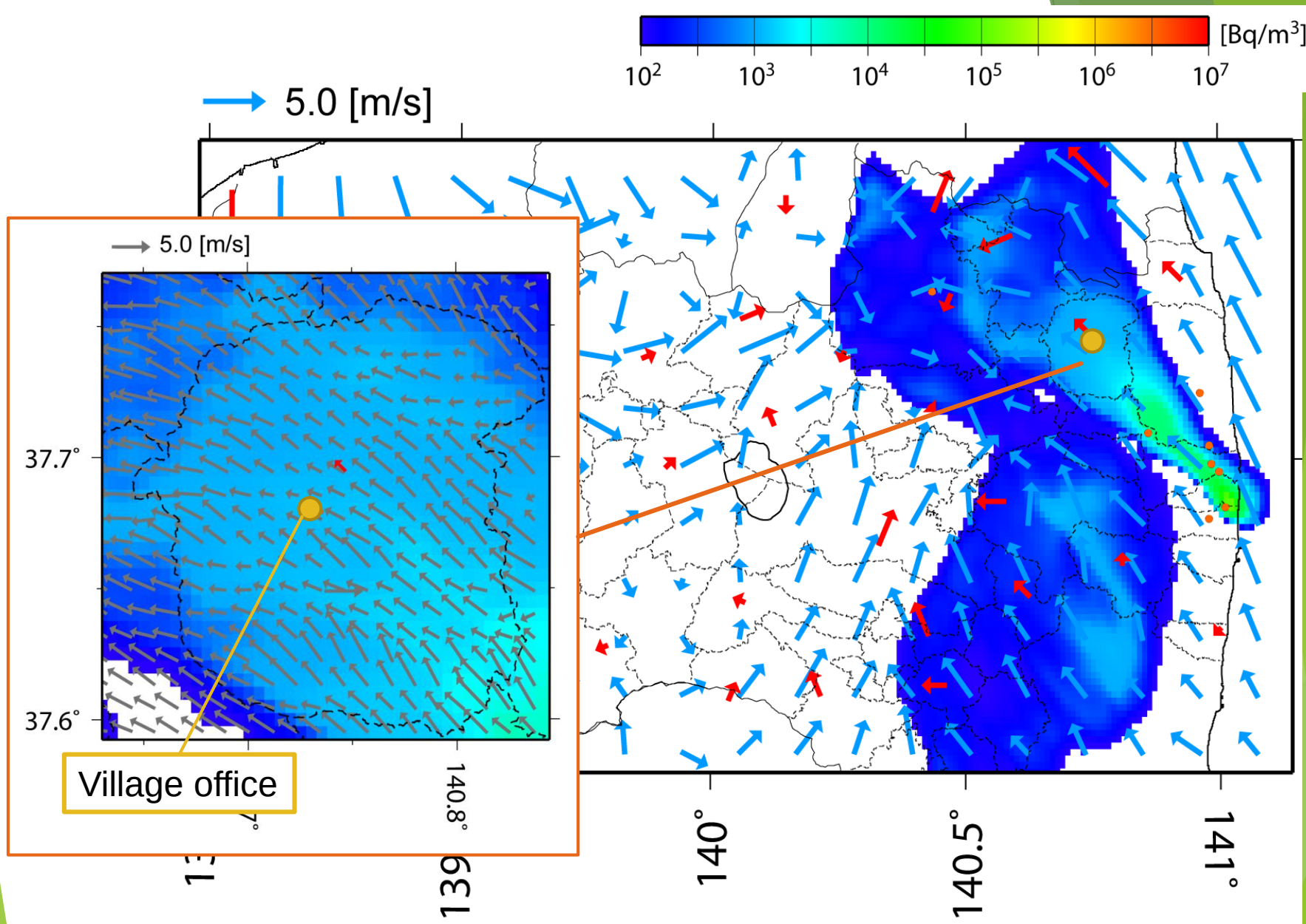
^{131}I atmospheric concentration (18:00 March 12, 2011)



^{131}I atmospheric concentration
(16:00 March 15 to 3:00 March 16, 2011)

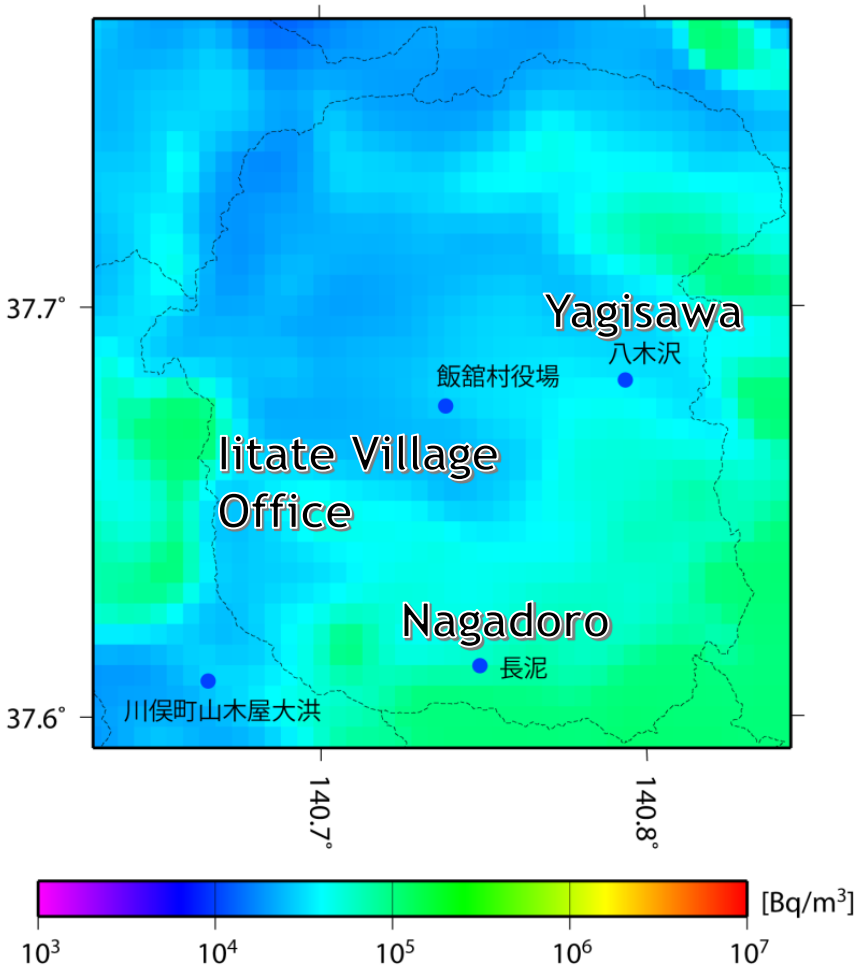


^{131}I atmospheric concentration (15:00 March 20, 2011)

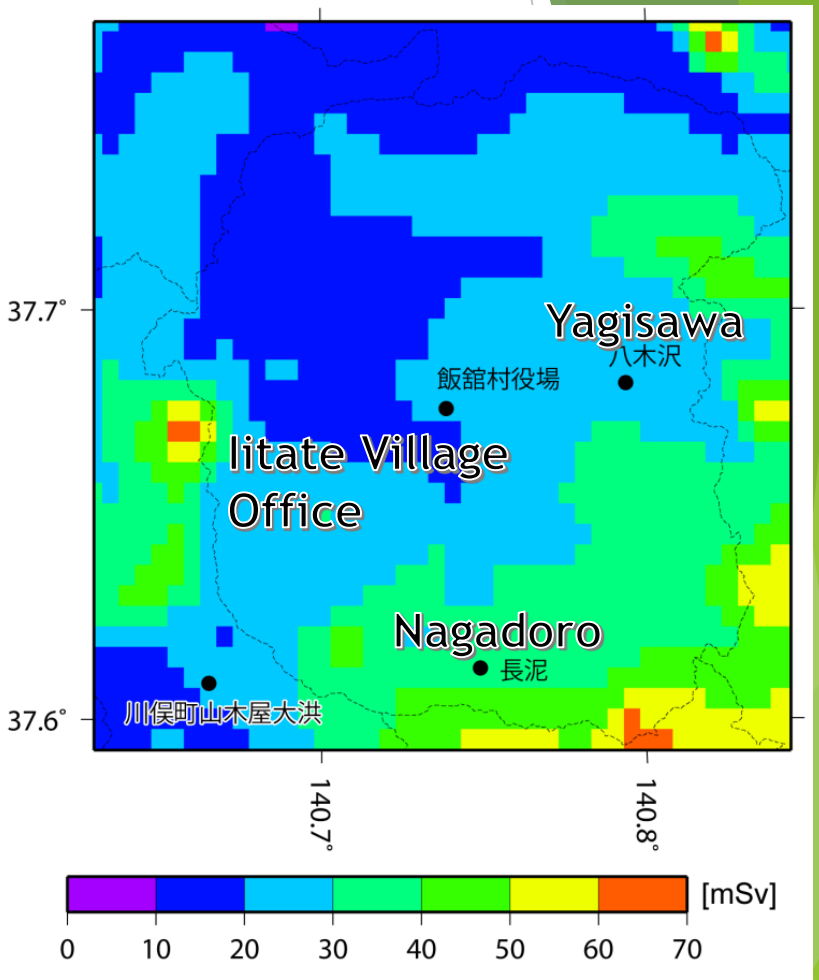


^{131}I atmospheric concentration (16:00 March 22, 2011)

Thyroid Equivalent Dose for Children due to ^{131}I Uptake



Time integrated concentration (March 12 – March 26)



The thyroid equivalent dose for children(March 12 – March 26)

Summary

When was ^{131}I deposited in Iitate ?

- The plume covered Iitate 4 times, at 18:30 March 12 , 19:00 to midnight March 15, 15:00 March 20 and 16:00 March 22, 2011.
- The contribution ratio of cumulative concentration were 17%, 54%, 13% and 16%, respectively

Thyroid equivalent dose for children of ^{131}I

Location	Time integrated Concentration (Bq/m^3*hr)	Thyroid equivalent dose for children (mSv)		
		Hours per day spent indoors(h)		
		0	16	24
MAX	$1.57x10^5$	67	34	17
Yagisawa	$6.11x10^4$	27	13	7
Nagadoro	$8.19x10^4$	36	18	9
Village office	$5.16x10^4$	22	11	6

The range of thyroid equivalent dose for children : 6-67mSv

Conclusion

Rapid Assessment

- Consistency between resulting plume movement and measured increase of dose rates suggests that the radioactive plume originated from 1F.
- Comparison of ^{137}Cs deposition between simulation and measurements in Kanto area were similar.
- Rapid assessment provides proper results even in a short period of time after the accident.

Detailed Assessment

- Detailed assessment for Iitate village was conducted and derived using time change of ^{131}I deposition.
- Resulting thyroid equivalent dose for children of ^{131}I varied between 6 and 67 mSv.